31 October 1963

MEMORANDUM FOR: Assistant for Plans and Development, NPIC

SUBJECT: Virtual Image Viewing

25X1A REFERENCE: [redacted] Proposal for Continuation of Work on Development of Virtual Image Viewer

25X1A The referenced proposal describes an R & D effort to develop a virtual image viewing device, by [redacted] in continuation of their previous program with [redacted] This particular technique of viewing holds much promise insofar as it eliminates one of the weakest links in the viewing chain - the screen. However, as the report on the first stages of development points out, there are many fundamental problems which must be solved before such a viewing device becomes useful.

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The basic problem in this system is the manufacture of the proper diffraction gratings. The line-spacing is of the order of 1000 cycles/inch and presents no problem at all, since ruling engines ordinarily cut 15,000 cycles or better. The proposal suggests that it is easily within the state-of-the-art to properly blaze the gratings so that the intensity within the first six or eight orders, on both sides of the central maximum, is uniform, or nearly so. This is patently not so. While the [redacted] 25X1A

25X1A [redacted] personnel are extremely competent in ruling technology, their final report specifically states that it will require a detailed, computerized study to determine the requisite blaze to the degree necessary; achieving it is problematical under nearly all circumstances.

It is believed that it is possible to achieve this equalization of diffraction order intensity by a revision of the optical system, or at least by an application of a basic coherent system technique. These principles can be applied to alleviating the stringent requirements on order equalization through specialized blazing, while utilizing the inherently superior diffraction afforded through gratings.

In a coherent optical system, a Fourier transform relates conjugate planes. If there are two such conjugate systems in cascade, an object passes through to become an aerial image, but transforms into a Fraunhofer diffraction pattern in an intermediate plane. More than this, if an object is placed in this intermediate plane, its diffraction pattern will be formed in the image plane.

If a periodic ruling (a diffraction grating, Ronchi ruling, etc.) is placed in the object plane, its diffraction pattern appears in the plane conjugate to the source. In both cases cited, the pattern will be a set of delta-functions, the intensities of the peaks being a complicated function of the ruling contours but their location a function of ruling period only. If two such rulings are aligned at right angles and used as objects, a set of delta-functions covers the entire plane. Such a set is shown in Figure 1. The rulings accounting for the horizontal and vertical components of the delta-functions were 800 and 400 cycles/inch respectively.

It can quite easily be shown that if these rulings were placed in the diffraction plane, and a photographic transparency were used as an object, the image would consist of a multiplicity of images, each centered about the separate delta-functions. However, these functions no longer exist as points. They have been used as "carriers" and the light which would ordinarily comprise this point has been modulated by the object to form an exact duplicate of the main image, displaced from it according to the nominal spacing of the delta-functions. This is, of course, the basis of virtual image viewing, insofar as its effect is to increase the exit pupil. Figure 3 is a photograph resulting from a crude experimental implementation of the system sketched in Figure 2a. An additional set of optics has been added to provide image enlargement up to approximately 4x. A photograph of the experimental set-up is shown in Figure 4.

The extra images in the vertical and horizontal directions in Figure 3 demonstrate the type of image which can be obtained. The quality of the secondary images is very low in this case, and the vertical images not adequately separated. This is a result of the poor quality of the rulings and the fact that to operate without phase distortion requires immersion of the rulings and object in a fluid gate of matching refractive index. However, these are experimental considerations which in no way should detract from the point being made. It is only necessary to point out that diffraction gratings of higher quality would improve image quality, but only if they were immersed or corrected for phase error.

Now up to this point, except for the image quality and the rearrangement of the optical elements in the system, the experimental viewer is no different from that proposed. There is the same problem involved in equalizing the diffraction orders; it is actually greater, since blaze has no meaning for Ronchi rulings. But consider utilizing the property of cascading conjugate planes. In the optical system of Figure 2b, which adds another pair of achromats, the rulings are used as objects. The diffraction pattern is formed, as before. But in this plane is inserted a spatial filter which consists of neutral densities placed in the path of the delta-functions, and whose values are so chosen that the intensity of the delta-functions is equalized over the plane. In forming an image analogous to that of Figure 1, such a filter would provide that all images, central-order included, would be of equal intensity.

The object is placed in the same plane as the spatial filter, but on the image side. Passing through two transformations (there are two sets of senses following it), it is imaged as before, and gives a multiplicity of equally intense images, as required. The stringent requirements on the diffraction gratings are thus removed by this technique, without impairing the imagery.

I would like to acknowledge the assistance of [redacted] in setting up the optical system, and [redacted] for his help with the photographic aspects of the problem.

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These considerations, of course, assume a number of things, and are in no way meant to furnish the design-concept of a new virtual image viewer. They require that the optical systems design be first-rate, particularly if the available source energy is to be usefully employed in image formation. They require that the system aperture, in the "image processing" region be large enough to accommodate all the spatial frequencies which constitute the image. In other words, the emphasis here is on optical-systems design rather than on an advancement of the state-of-the-art in diffraction grating production.

This way of achieving virtual-image viewing is not especially advocated. The discussions here are meant to show that there are other ways around the problem; they represent suggestions or ideas, which perhaps ought to be discussed with the contracting people.

[redacted]

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Chief, Exploratory Development Laboratory Branch
P&DS, NPIC

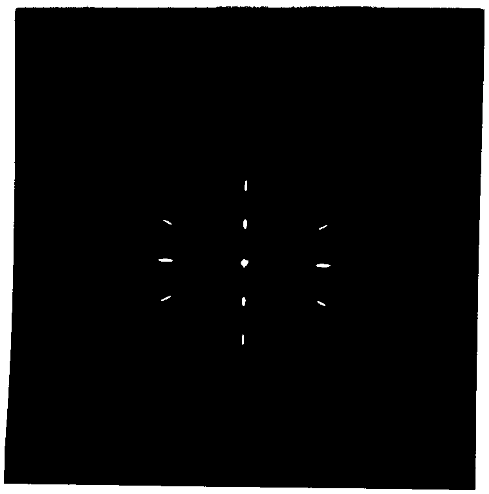
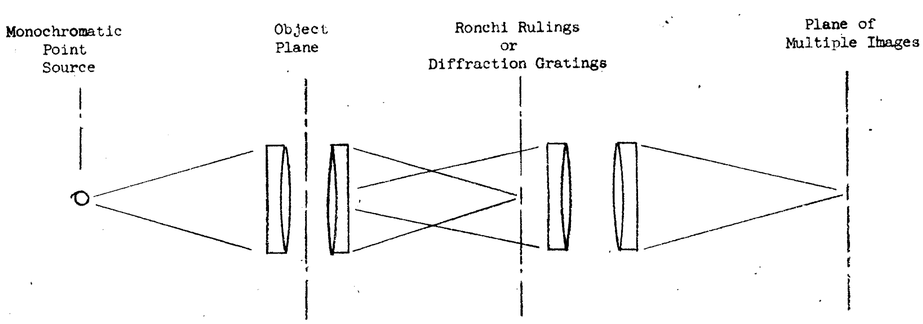
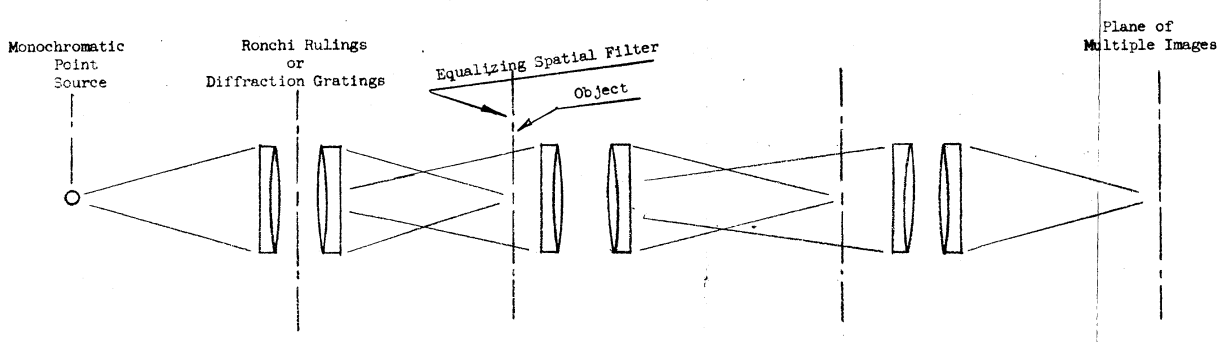


Figure 1: Photograph of the diffraction pattern resulting from two Ronchi rulings whose lines have been oriented at right angles to each other. The illumination was from a concentrated arc lamp filtered through a Wratten #58 filter. This rendered the delta-functions elliptical because of the wave-length spread. It is further complicated by the quadratic phase error resulting from the lens arrangement. Both effects can be eliminated when necessary.



a) Without equalization of Fraunhofer orders.



b) With equalization of Fraunhofer orders.

Figure 2: Optical schematic for system to produce multiple images; to be enlarged and used in a virtual image viewer.

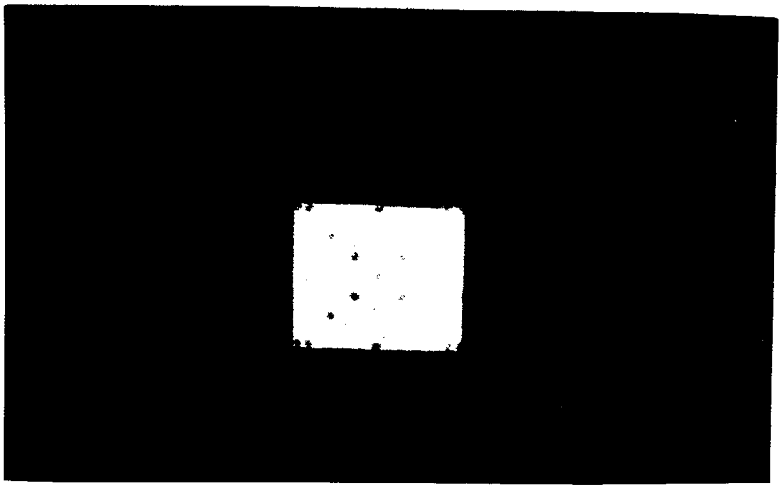


Figure 3: Photograph of the multiple images produced by the experimental optical system of Figure 4. Because of the imperfections within the object itself, the lack of general image intensity, and the misalignments of the system elements, no serious attempt was made to obtain a well-focussed image, nor to rectify the apparent image exposure differential through printing techniques.

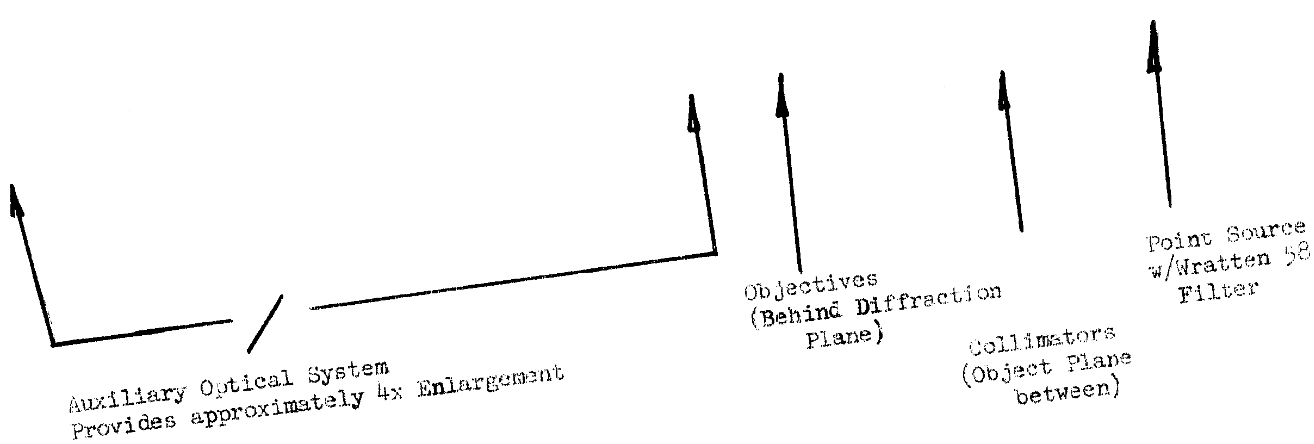


Figure 4: Photograph of experimental optical system in which the multiple images were produced. The two Ronchi rulings are shown taped in position behind the Objectives, and the object between the collimators. The point source is behind the cardboard mask which is used to hold the Wratten #58 and to baffle the stray light. The image is formed approximately 18 inches beyond the last element in the auxiliary optical system.